Missouri Department of Transportation

Bridge Division

Bridge Design Manual

Section 1.2

Revised 08/08/2002

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Index of Loads

1.2.1 General

AASHTO 3.2

Structures shall be designed to carry the dead load, live load, impact (or dynamic effect of the live load), wind load and other forces, when they are applicable.

Members shall be designed with reference to service loads and allowable stresses as provided in AASHTO Service Load Design Method (Allowable Stress Design) or with reference to factored load and factored strength as provided in AASHTO Strength Design Method (Load Factor Design). Load groups represent various combination of loads and forces to which a structure may be subjected. Group loading combinations for Service Load Design and Load Factor Design are given by AASHTO 3.22.1 and AASHTO Table 3.22.1A.

1.2.2 Dead Load

Dead Load shall include the gravity force (weight) of all components of the structure. In the absence of more precise information, the unit weights, specified in the following table, may be used for dead load.

AASHTO 3.3.6

Unit Weight of Materials	
Reinforced Concrete	150 lb/ft^3
Concrete	144 lb/ft^3
Asphaltic Concrete	154 lb/ft^3
Light Weight Concrete	110 lb/ft^3
Structural Steel	490 lb/ft^3
Oak	50 lb/ft^3
Southern Pine	38 lb/ft^3
Southern Pine (Creosoted)	50 lb/ft^3
Aluminum Alloys	175 lb/ft^3
Earth	120 lb/ft^3
Bituminous Surface	140 lb/ft^3
Future Wearing Surface (*)	35 lb/ft^2

(*) Based on 3 inch thickness, this load is not to be included in dead load deflection computations.

1.2.3 Live Load

AASHTO 3.4 & 3.7

The live load shall consist of the applied moving load of vehicles and pedestrians. The design live load to be used in the design of bridges for the state system will be as stated on the Design Layout.

- The design truck:
  HS20-44 or HS20-44 Modified
- The design tandem (Military)
- The design lane loading

Criteria

AASHTO 3.24.3

1 All new bridges on the National Highway System and in commercial zones are to be designed for HS20-44 Modified loading. All remaining bridges will be designed for HS20-44 loading.
2 The Design Tandem loading is to be checked on national highway system or when Alternate Military loading appears on the Design Layout.
3 Carrying members of each structure shall be investigated for the appropriate loading.
  Main carrying members include:
  - Steel or Concrete stringers or girders.
  - Longitudinally reinforced concrete slabs supported on transverse floor beams or substructure units (includes hollow slabs).
  - Transversely reinforced concrete slabs supported by main carrying members parallel to traffic and over 8'-0" center to center. Use the formulas for moment in *AASHTO Article 3.24.3.1 Case A.*
  - Steel grid floors when the main elements of the grid extend in a direction parallel to traffic, or with main elements transverse to traffic on supports more than 8'-0" apart.
  - Timber floors and orthotropic steel decks.

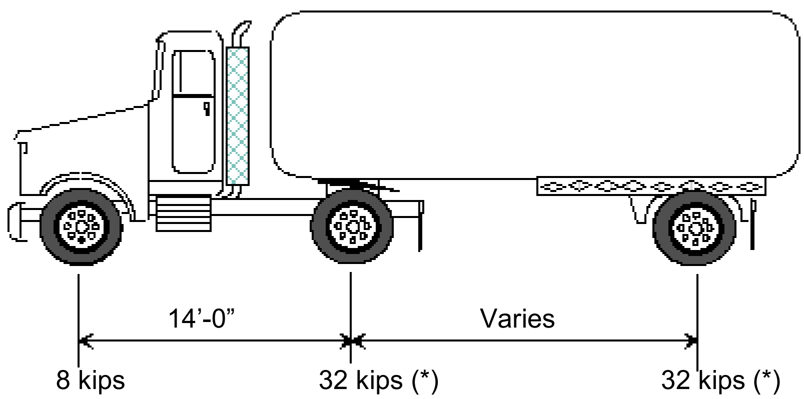
AASHTO 3.12

4 The reduction in live load for calculating substructure members is based on *AASHTO 3.12.1.* See *Live Load Distribution* in the *Load Distribution* Section.

HS20-44 Truck Loading

AASHTO 3.7.6

The HS20-44 truck is defined below as one 8 kip axle load and two 32 kip axle loads spaced as shown.



Varies = Variable spacing 14' to 30' inclusive. Spacing to be used is that which produces the maximum stresses.

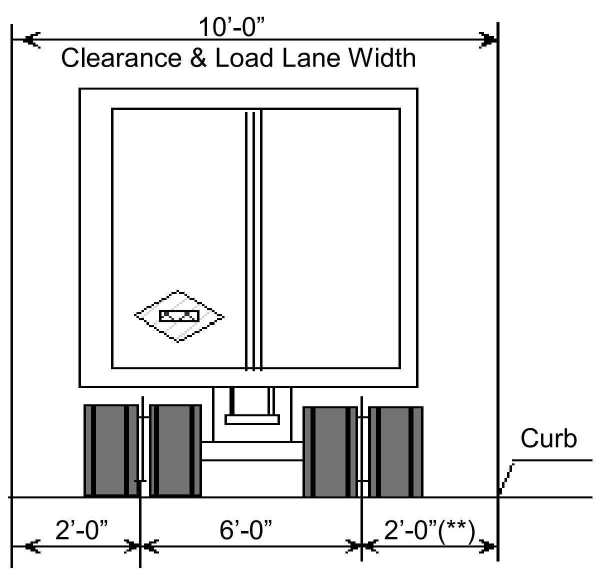


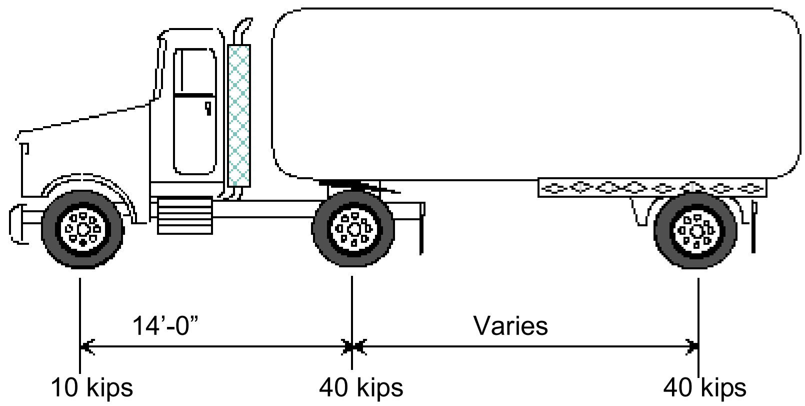
Figure 1.2.3-1 HS20-44 Design Truck

(*) In the design of timber floors and orthotropic steel decks (excluding transverse beams) for H-20 Loading, one axle load of 24 kips or two axle loads of 16 kip each, spaced 4 feet apart may be used, whichever produces the greater stress, instead of the 32 kip axle load shown.

(**) For slab design, the center line of wheels shall be assumed to be one foot from face of curb.

HS20-44 Modified Truck Loading

The HS20-44 Modified truck is defined below as one 10 kip axle load and two 40 kip axle loads spaced as shown. This is the same as HS20-44 truck modified by a factor of 1.25.



Varies = Variable spacing 14’ to 30’ inclusive. Spacing to be used is that which produces the maximum stresses.

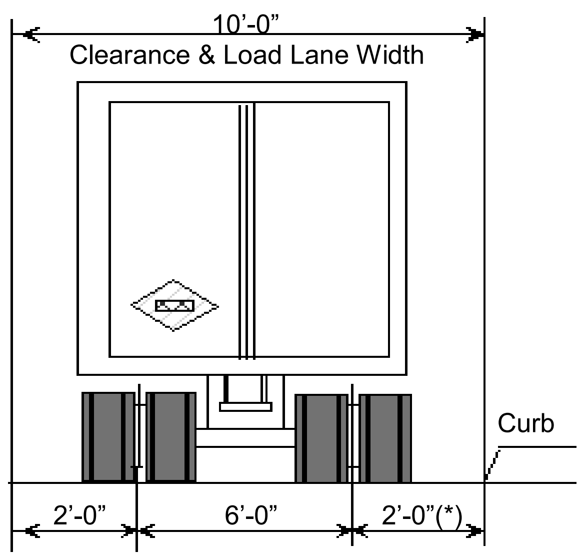


Figure 1.2.3-2 HS20-44 Modified Design Truck

(*) For slab design, the center line of wheels shall be assumed to be one foot from face of curb.

Design Tandem Loading

AASHTO 3.7.4

The Design Tandem Loading is a two axle load each of 24 kips. These axles are spaced at 4'-0" centers. The transverse spacing of wheels shall be taken as 6'-0" (Figure 1.2.3-3).

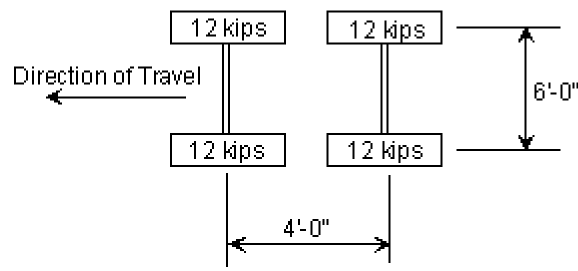


Figure 1.2.3-3 Design Tandem Loading - Plan View

Design Lane Loading

- For HS20-44 Truck, the design lane load shall consist of a load 640 lbs per linear foot, uniformly distributed in the longitudinal direction with a single concentrated load (or two concentrated loads in case of continuous spans for determination of maximum negative moment), so placed on the span as to produce maximum stress. The concentrated load and uniform load shall be considered as uniformly distributed over a 10'-0" width on a line normal to the center line of the lane (Figure1.2.3-4).

- For HS20-44 Modified Truck, use the HS20-44 truck modified by a factor of 1.25 (Figure 1.2.3-4).

AASHTO 3.7.6

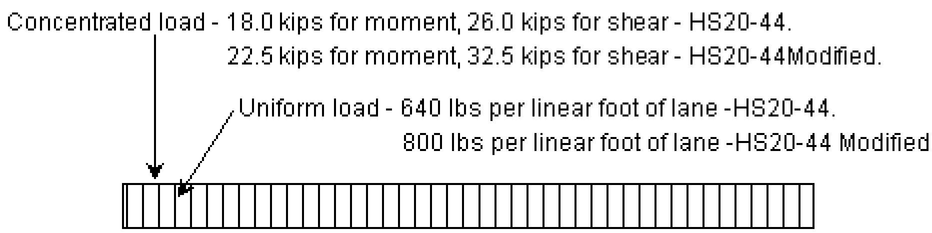


Figure 1.2.3-4 Design Lane Loading

AASHTO 3.11.1, 3.11.2

- For the design of continuous structures, an additional concentrated load is placed in another span to create the maximum effect. For positive moments, only one concentrated load is used, combined with as many spans loaded uniformly as are required to produce the maximum moment.

Standard Roadway Width

26'-0" (up to 2 traffic lanes) (*)
28'-0" (up to 2 traffic lanes) (*)
30'-0" (up to 3 traffic lanes) (*)
32'-0" (up to 3 traffic lanes) (*)
36'-0" (up to 3 traffic lanes) (*)
38'-0" (up to 3 traffic lanes) (*)
40'-0" (up to 4 traffic lanes) (*)
44'-0" (up to 4 traffic lanes) (*)

(*) See page 3-6 thru 3-8 of this section.

DESIGN LANE LOADINGS (CONT.) **Live Loads**

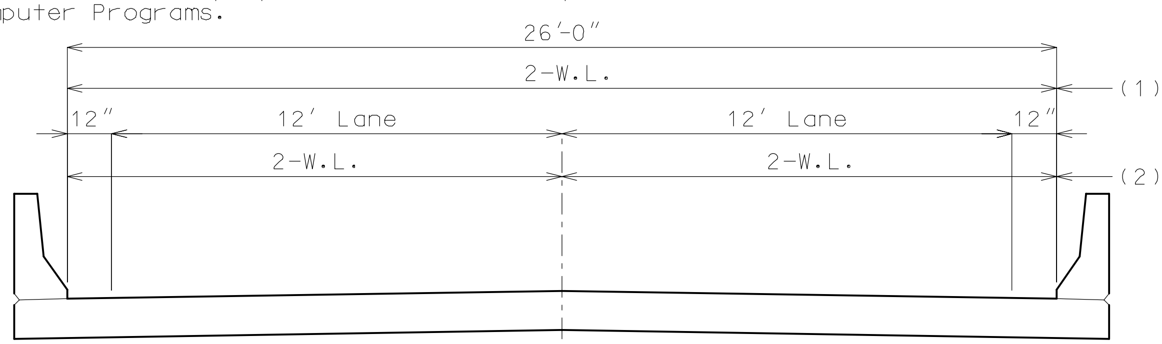
STANDARD ROADWAY WIDTH (CONT.)

TRAFFIC LANE FOR DESIGN

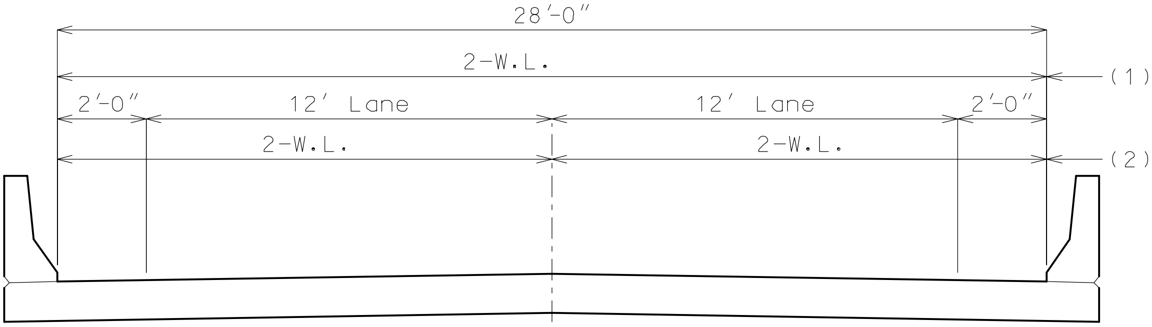
The following number of wheel lines (shown in the details below and subsequent sheets) will be used for the design of superstructure and substructure.

Note to Designers:

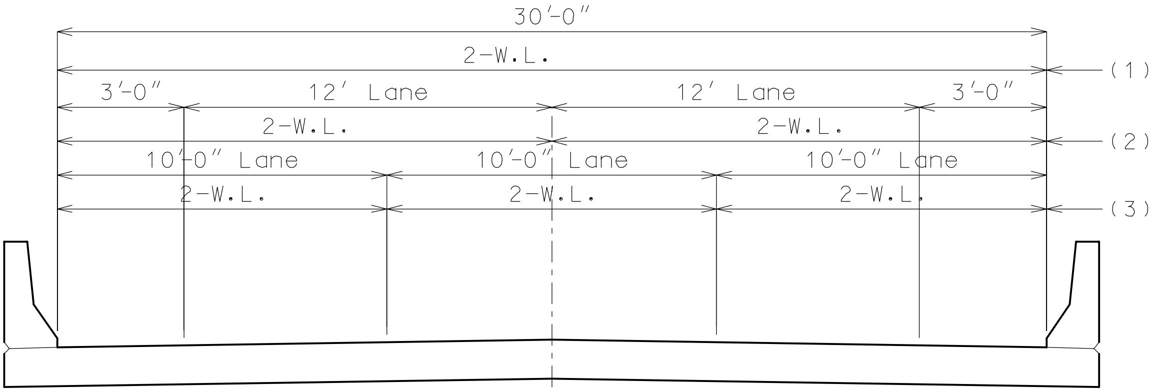
Be sure that the proper lane width is Input into the "STRESS" and/or "BR409" Computer Programs.



26'-0" ROADWAY WIDTH



28'-0" ROADWAY WIDTH



30'-0" ROADWAY WIDTH

In compliance with AASHTO - Article 3.12 the following number of wheel lines will be used.

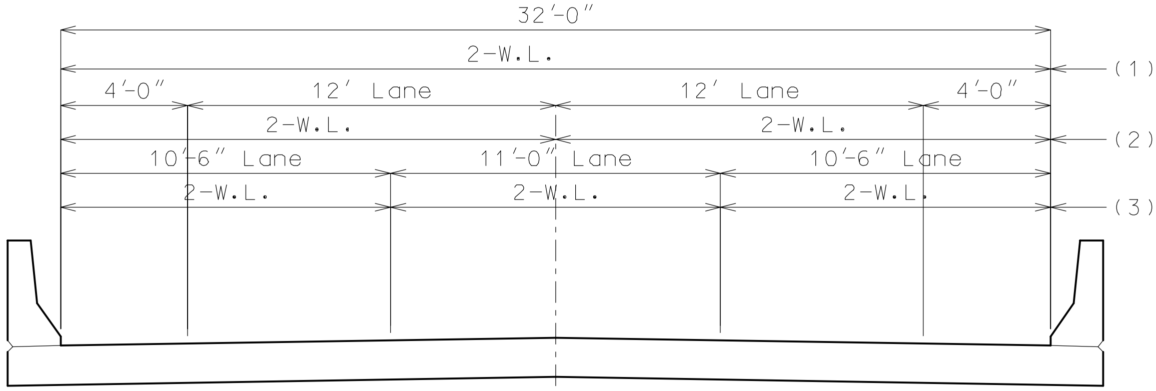
(1) <u>2</u> Wheel lines at 100% placed anywhere.

(2) Any combination of <u>4</u> Wheel lines at 100% (2 within a lane).

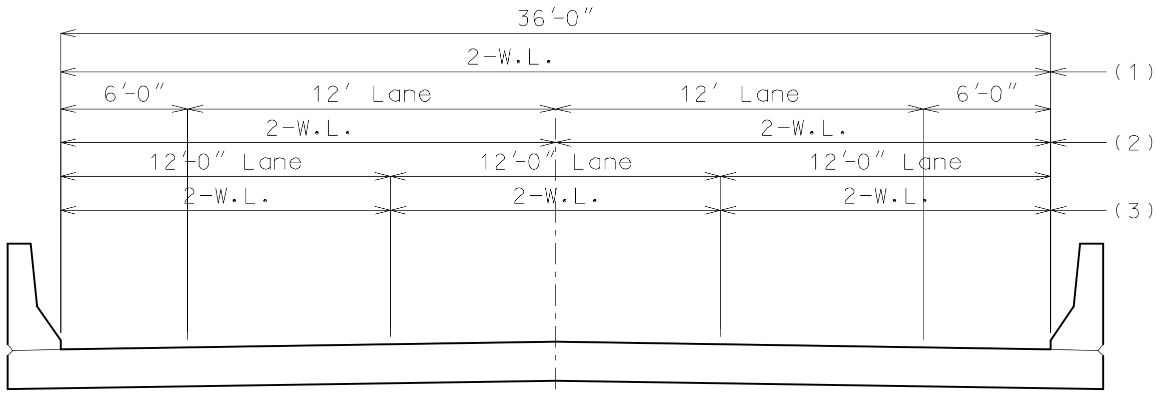
(3) <u>6</u> Wheel lines at 90% (2 within a lane).

DESIGN LANE LOADINGS (CONT.) **Live Loads**

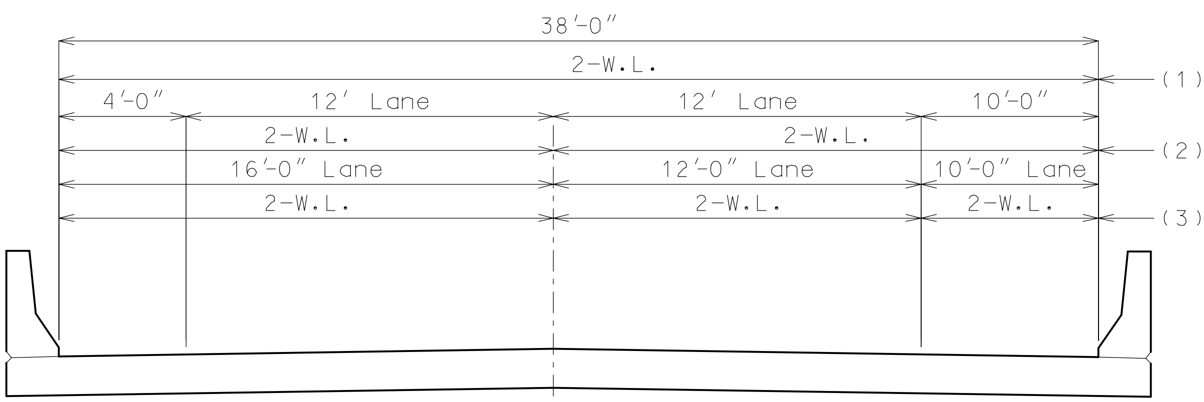
STANDARD ROADWAY WIDTH (CONT.)



32'-0" ROADWAY WIDTH



36'-0" ROADWAY WIDTH



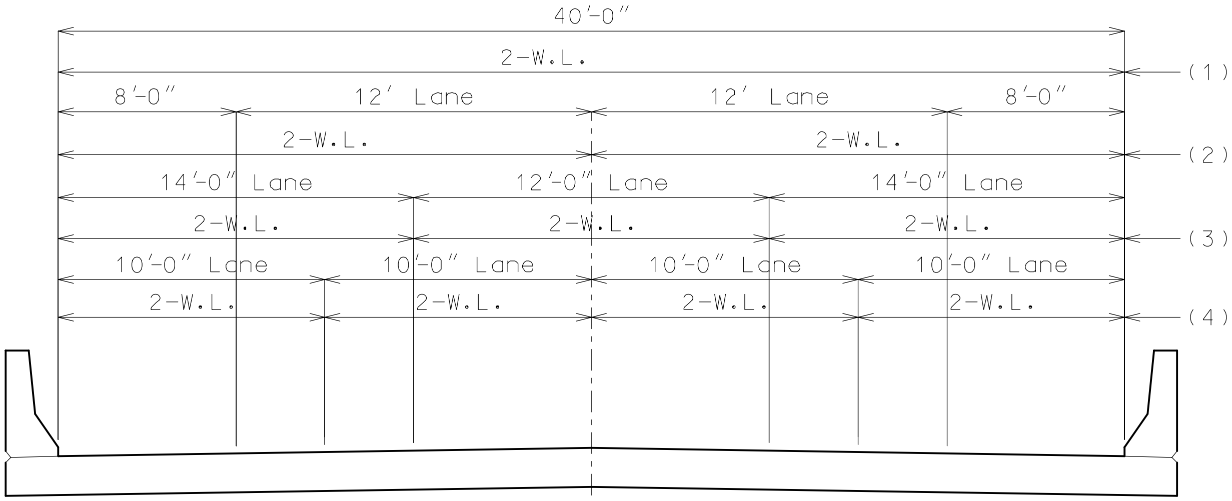
38'-0" ROADWAY WIDTH (UNSYMMETRICAL)

In compliance with AASHTO - Article 3.12 the following number of wheel lines will be used.

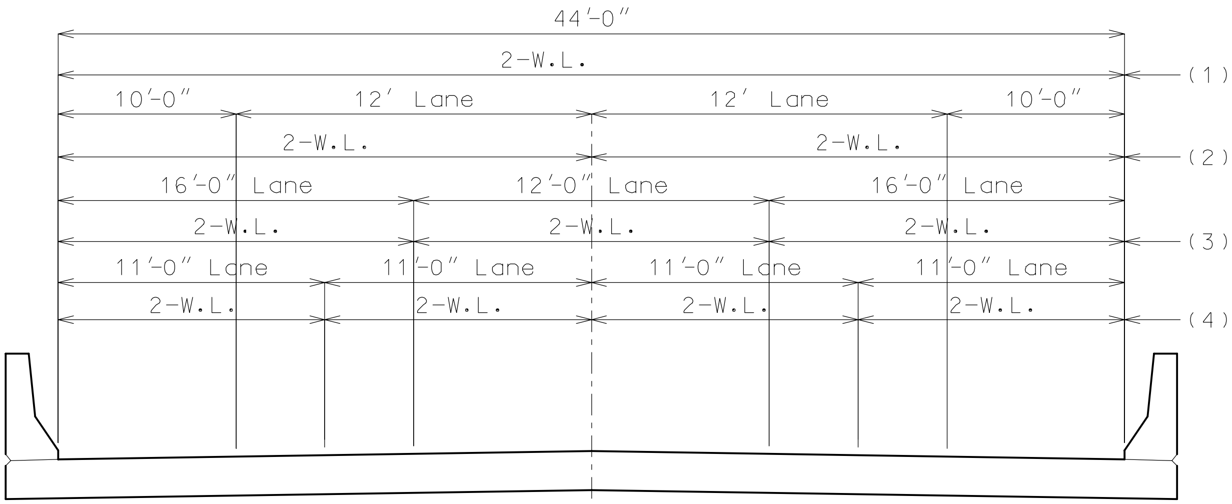
(1) 2 Wheel lines at 100% placed anywhere.

(2) Any combination of 4 Wheel lines at 100% (2 within a lane).

(3) 6 Wheel lines at 90% (2 within a lane).



40'-0" ROADWAY WIDTH



44'-0" ROADWAY WIDTH

In compliance with AASHTO - Article 3.12 the following number of wheel lines will be used.

(1) 2 Wheel lines at 100% placed anywhere.

(2) Any combination of 4 Wheel lines at 100% (2 within a lane).

(3) 6 Wheel lines at 90% (2 within a lane).

(4) 8 Wheel lines at 75% or (any combination of), 6 Wheel lines at 90%, 4 Wheel lines at 100%, 2 Wheel lines at 100% (2 within a lane).

1.2.4 Impact

AASHTO 3.8.2.1

Highway live loads shall be increased by a factor given by the following formula:

$$I = \frac{50}{L + 125} \quad \textit{L in feet}$$

For continuous spans, ***L*** to be used in this equation for negative moments is the average of two adjacent spans at an intermediate bent or the length of the end span at an end bent. For positive moments, ***L*** is the span length from center to center of support for the span under consideration.

Impact is never to be more than 30 percent. It is intended that impact be included as part of the loads transferred from superstructure to substructure but not in loads transferred to footings or parts of substructure that are below the ground line. The design of neoprene bearing pads also does not include impact in the design loads.

1.2.5 Collision Force

AASHTO 2.7.1.3

Collision forces shall be applied to the barrier curb in the design of the cantilever slab. A force of 10 kips is to be applied at the top of the standard barrier curb. This force is distributed through the barrier curb to the slab as explained in the slab design assumptions in the *General Superstructure* Section.

AASHTO Figure 2.7.4B

A collision force of 10 kips is also applied to retaining walls when the wall serves as a grade separation between two roadways or acts to elevate the roadway from the surrounding terrain. This impact load of 10 kips shall be applied at a point 3'-0" above the driving surface of the upper roadway. If the height of the wall from the driving surface is less than 3'-0", the impact load shall be applied at the top of the wall. For more information on the distribution of this force, see *Retaining Wall* Section.

1.2.6 Centrifugal Force

Structures on curves shall be designed for a horizontal radial force equal to the following percentage of the live load in all the lanes, without impact.

$$C = \frac{6.68S^2}{R}$$

Where

C = the centrifugal force in percent of the live load
S = the design speed in miles per hour
R = the radius of the curve in feet

AASHTO 3.10.1

This force shall be applied at 6 feet above the centerline of the roadway with one design truck being placed in each lane in a position to create the maximum effect. Lane loads shall not be used in calculating centrifugal forces.

The effects of superelevation shall be taken into account.

1.2.7 Lateral Earth Pressure

Static

AASHTO 3.20

Structures which retain fills shall be designed for active earth pressures as

$$P_a = 0.5\ (\gamma\ K_a)\ H^2$$

where

P_a = active earth pressure per length (lb/ft)
γ = unit weight of the back fill soil = 120 lb/ft^3
K_a = coefficient of active earth pressure as given by Rankine's formula
$\gamma\ K_a = p_a$ = equivalent fluid pressure (lb/ft^3) (*)
H = height of the back fill soil (ft)

Rankine's Formula

AASHTO 3.20.1

The coefficient of active earth pressure K_a is

$$K_a = (\cos\alpha)\left(\frac{\cos\alpha - \sqrt{\cos^2\alpha - \cos^2\phi}}{\cos\alpha + \sqrt{\cos^2\alpha - \cos^2\phi}}\right)$$

where

ϕ = angle of internal friction of the backfill soil (*)
α = the angle of incline of the backfill

If the backfill surface is level, angle α is zero and K_a is

$$K_\alpha = \frac{1 - \sin\phi}{1 + \sin\phi}$$

(*) Use the internal friction angle indicated on the Design Layout. However, if the friction angle is not determined, use the minimum equivalent fluid pressure value, p_a, of 45 lb/ft^3 for bridges and retaining walls. For box culverts use a maximum of 60 lb/ft^3 and a minimum of 30 lb/ft^3 for fluid pressure.

Live Load Surcharge

AASHTO 3.20.3

An additional earth pressure shall be applied to all structures which have live loads within a distance of half the structure height. This additional force shall be equal to adding 2'-0" of fill to that presently being retained by the structure. See *Retaining Wall* Section.

Dynamic

AASHTO Specifications, Division IA, Section 5, 6

No consideration of seismic forces is required for bridges in Seismic Performance Category A except for the design of the connection of the superstructure to the substructure.

In Seismic Performance Categories B, C and D use the Mononobe-Okabe equation given in the *AASHTO -Seismic Design Commentary.*

See *Seismic Design* Sections.

1.2.8 Longitudinal Forces (Braking Forces)

AASHTO 3.9

A longitudinal force of 5% of the live load shall be applied to the structure. This load shall be 5% of the lane load plus the concentrated load for moment applied to all lanes and adjusted by the lane reduction factor. Apply this force at 6 feet above the top of slab and to be transmitted to the substructure through the superstructure.

1.2.9 Wind Load

AASHTO 3.15

Wind loads shall be applied to the structure regardless of length.

The pressure generated by wind load is

$$P = K V^2$$

where

P = wind pressure in pounds per square foot
V = design wind velocity = 100 miles per hour
K = 0.004 for wind load
Basic wind load (pressure) = $0.004 \times (100)^2 = 40$ lb/ft^2

Wind Load for Superstructure Design

AASHTO 3.15.1

<u>Transverse</u>

A wind load of the following intensity shall be applied horizontally at right angles to the longitudinal axis of the structure.

AASHTO 15.1.1.2

- Trusses and Arches = 75 pounds per square foot = W_t
- Girders and Beams = 50 pounds per square foot (*) = W_t (for plate girder lateral bracing check only)
- The total force shall not be less than 300 pounds per linear foot in the plane of windward chord and 150 pounds per linear foot in the plane of the leeward chord on truss spans, and not less than 300 pounds per linear foot on girder spans.

Wind Load for Substructure Design

AASHTO 3.15.2

Forces transmitted to the substructure by the superstructure and forces applied directly to the substructure by wind load shall be as follows:

Forces from Superstructure: Wind on Superstructure

<u>Transverse</u>

A wind load of the following intensity shall be applied horizontally at right angles to the longitudinal axis of the structure.

AASHTO 3.15.2.1.1

- Trusses and Arches = 75 pounds per square foot = W_t
- Girders and Beams = 50 pounds per square foot (*) = W_t

(*) Use W_t = 60 lbs/ft^2 for design wind force on girders and beams If the column height on a structure is greater than 50 feet, where the height is the average column length from ground line to bottom of beam.

The transverse wind force for a bent will be

$$P = L \times H \times W_t$$

where
- L = length in feet = the average of two adjacent spans for intermediate bents and half of the length of the end span for end bents.
- H = the total height of the girders, slab, barrier curb and any superelevation of the roadway, in feet
- W_t = wind force per unit area in pounds per square foot

This transverse wind force will be applied at the top of the beam cap for the design of the substructure.

Longitudinal (**)

The standard wind force in the longitudinal direction shall be applied as a percentage of the transverse loading. Use approximately 25%.

AASHTO 3.15.2.1.3

Truss and Arch Structures	W_l = 75x0.25 = approximately 20 lbs/ft^2
Girder Structures	W_l = 50x0.25 = approximately 12 lbs/ft^2

The total longitudinal wind force P will be

$$P = L \times H \times W_l$$

where
- L = the overall bridge length in feet
- H = the total height of the girders, slab, barrier curb and any superelevation of the roadway, in feet
- W_l = wind force per unit area in pounds per square foot

This longitudinal force is distributed to the bents based on their stiffness. (**) The longitudinal wind force for the bent will be applied at the top of the beam cap for the design of the substructure.

Forces from Superstructure: Wind on Live Load

AASHTO 3.15.2.1.3

A force of 100 pounds per linear foot of the structure shall be applied transversely to the structure along with a force of 40 pounds per linear foot longitudinally. These forces are assumed to act 6 feet above the top of slab.

The transverse force is applied at the bents based on the length of the adjacent spans affecting them. The longitudinal force is distributed to the bents based on their stiffness. (**)

(**) See Longitudinal Distribution of Wind Loads in Distribution of Loads Section.

Forces Applied Directly to the Substructure

AASHTO 3.15.2.2

The transverse and longitudinal forces to be applied directly to the substructure elements shall be calculated from an assumed basic wind force of 40 lbs/ft^2. This wind force per unit area shall be multiplied by the exposed area of each substructure member in elevation (use front view for longitudinal force and side view for transversely force, respectively). These forces are acting at the center of gravity of the exposed portion of the member.

A shape factor of 0.7 shall be used in applying wind forces to round substructure members.

When unusual conditions of terrain or the special nature of a structure indicates, a procedure other than the Standard Specification may be used subject to approval of the Structural Project Manager.

1.2.10 Temperature Forces

AASHTO 3.16

Temperature stresses or movement need to be checked on all structures regardless of length. Generation of longitudinal temperature forces is based on stiffness of the substructure. (*)

Coefficients

Steel: Thermal - 0.0000065 ft/ft/°F

Concrete: Thermal - 0.0000060 ft/ft/°F
Shrinkage - 0.0002 ft/ft (***)
Friction - 0.65 for concrete on concrete

Temperature Range From 60° F (**)

	Rise	**Fall**	**Range**
Steel Structures	60°F	80°F	140°F
Concrete Structures	30°F	40°F	70°F

(*) See Longitudinal Distribution of Temperature Forces in Distribution of Loads Section.

(**) Temperature Range for expansion bearing design and expansion devices design see Bearing Section, Expansion Devices Section, respectively.

(***) When calculating substructure forces of concrete slab bridges, the forces caused by the shrinkage of the superstructure should be included with forces due to temperature drop. This force can be ignored for most other types of bridges.

1.2.11 Earthquake Loads

For Seismic Performance Categories A, B, C and D, see *Seismic Design* Section.

1.2.12 Sidewalk Loading

AASHTO 3.14.1.1

Sidewalk floors and their immediate support members shall be designed for a **live load** of 85 pounds per square foot of sidewalk area. Girders, trusses, and other members shall be design for the following sidewalk live load:

Spans 0 to 25 feet	85 lbs/ft^2
Spans 26 to 100 feet	60 lbs/ft^2
Spans over 100 feet	use the following formula

$$P = (30 + \frac{3000}{L})(\frac{55 - W}{50})$$

where

P = live load per square foot, max. 60 lbs/ft^2
L = loaded length of sidewalk in feet
W = width of sidewalk in feet

AASHTO 3.14.1.2

For cantilevered sidewalks, the sidewalk shall be fully loaded on just one side of the structure if this produces the maximum stresses.

AASHTO 3.22.1
AASHTO 3.23.2.3.1.3

When sidewalk live loads are applied along with live load and impact, if the structure is to be designed by service loads, the allowable stress in the outside beam or stringer may be increased by 25 percent as long as the member is at least as strong as if it were not designed for the additional sidewalk load using the initial allowable stress. When the combination of sidewalk live load and traffic live load plus impact governs the design under the load factor method, use a β factor of 1.25 instead of 1.67.

Unless a more exact analysis can be performed, distribution of sidewalk live loads to the supporting stringers shall be considered as applied 75 percent to the exterior stringer and 25 percent to the next stringer.

1.2.13 Other Loads

Stream Pressure

Stream flow pressure shall be considered only in extreme cases. The affect of flowing water on piers shall not be considered except in cases of extreme high water and when the load applied to substructure elements is greater than that which is applied by wind on substructure forces at low water elevations.

AASHTO 3.18.1

The pressure generated by streamflow is

$$P = KV^2$$

AASHTO 3.18.1.1

Where

P = stream pressure in pounds per square foot
V = design velocity of water in feet per second
K = shape constant for the surface the water is in contact with.
  K = 1.4 for square-ended piers
  K = 0.7 for circular piers
  K = 0.5 for angle-ended piers where the angle is 30 degrees or less

Ice Forces

AASHTO 3.18.2

Ice forces on piers shall be applied if they are indicated on the Design Layout.

Buoyancy

AASHTO 3.19

Buoyancy shall be considered when its effects are appreciable.

Fatigue in Structural Steel

Steel structures subjected to continuous reversal of loads are to be designed for fatigue loading. See *Unit Stresses* Section.

Prestressing

See *P/S Concrete Girders* Section.

Other Loads

Other loads may need to be applied if they are indicated on the Design Layout. Otherwise see Structural Project Manager before applying any additional loads.

1.2.14 Group Loading

AASHTO 3.22

Group Loading (Service Load Design)

Group loading combinations are:

AASHTO Table 3.22.1A

GP I SL	=	D+L+I	100%
GP II SL	=	D+W	125%
GP III SL	=	D+L+I+0.3W+WL+LF	125%
GP IV SL	=	D+L+I+T	125%
GP V SL	=	D+W+T	140%
GP VI SL	=	D+L+I+0.3W+WL+LF+T	140%

where
D = dead load
L = live load
I = live load impact
W = wind load on structure
WL = wind load on live load
T = temperature force
LF = longitudinal force from live load

Group Loading (Load Factor Design)

Group loading combinations are:

AASHTO Table 3.22.1A

GP I LF = $1.3[\beta_d D+1.67 (L+I)]$
GP II LF = $1.3[\beta_d D+W]$
GP III LF = $1.3[\beta_d D+L+I+0.3W+WL+LF]$
GP IV LF = $1.3[\beta_d D+L+I+T]$
GP V LF = $1.25[\beta_d D+W+T]$
GP VI LF = $1.25[\beta_d D+L+I +0.3W+WL+LF+T]$

where
D = dead load
L = live load
I = live load impact
W = wind load on structure
WL = wind load on live load
T = temperature force
LF = longitudinal force from live load
β_d = coefficient, see AASHTO Table 3.22.1A

Other group loadings in AASHTO Table 3.22.1A shall be used when they apply.